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G- AND KI-PAN SEMICONDUCTOR TR DEVICE

Report No. 1

Contract No. DA-20-044-MC-115 (6)

DA-Task #19 (10) (A)

THIRD QUARTERLY PROGRESS REPORT

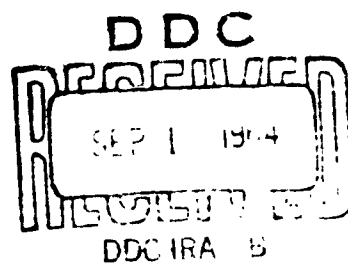
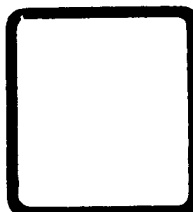
1 January 1964 - 31 March 1964

Project No. IG-1001A

U.S. ARMY ELECTRONIC LABORATORY

FORT MONMOUTH, NEW JERSEY

MICRONAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS



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C- AND Ku-BAND SEMICONDUCTOR TR DEVICES

Report No. 3

Contract No. DA-36-039-AMC-03187(E)

THIRD QUARTERLY PROGRESS REPORT

1 January 1964 - 31 March 1964

Project No. 1G6 22001 A 056

The purpose of this Contract is to design, develop and construct high power semiconductor TR devices with electrical properties similar to those of gaseous type TR tubes.

Placed by:

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I. PURPOSE

The purpose of this contract is to design, develop and construct high power semiconductor TR devices with electrical properties similar to those of gaseous type TR tubes. The function of these devices is to isolate a receiver during high power transmission periods to prevent damage to sensitive receiver elements and, after transmission, to rapidly provide a low attenuation path between receiver and antenna.

Performance characteristics considered as design objectives for the C- and Ku-band TR devices are shown in Table I.

TABLE I

C-BAND

<u>CHARACTERISTIC</u>	<u>SYMBOL</u>	<u>OBJECTIVES</u>		<u>UNITS</u>
		<u>MAX.</u>	<u>MIN.</u>	
Peak Operating Power	P_o	5	---	KW
Average Operating Power	P_{oa}	5	---	watts
Frequency Range	F	5.75	5.25	Gc/s
Insertion Loss	L_i	0.7	---	db
Flat Leakage Power	P_f	50	---	mw
Spike Leakage Energy	W_s	.4	---	ergs
Recovery Time	t	0.1	---	μ sec
Ambient Temperature	T	+150	-50	$^{\circ}$ C

Ku-BAND

Peak Operating Power	P_o	1	---	KW
Average Operating Power	P_{oa}	1	---	watts
Frequency Range	F	16.5	16.0	Gc/s
Insertion Loss	L_i	0.8	---	db
Flat Leakage Power	P_f	30	---	mw
Spike Leakage Energy	W_s	0.2	---	ergs
Recovery Time	t	0.1	---	μ sec
Ambient Temperature	T	+150	-50	$^{\circ}$ C

II. ABSTRACT

This report covers work performed during the quarterly period 1 January 1964 to 31 March 1964. No work was performed on the C-band portion of this contract during this period.

All work performed on the Ku-band investigation during this period was concerned with full height Ku-band waveguide diode mounts. PIN and varactor diodes have been measured using forward DC bias to simulate high power isolation and zero bias to provide the low loss condition. Additional work has been carried out utilizing high burn out crystal detectors to provide the forward bias for the PIN and the varactor during high power tests. High power tests during this quarterly interval resulted in the successful operation of a two stage switched limiter. Operational data is given for peak powers up to 1,000 watts.

III. PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

During this quarterly period, there were no publications, lectures or reports pertaining to this contract.

On 11 March 1964, Mr. W. Matthei of USAERDL, Fort Monmouth, N. J. visited the facilities of Microwave Associates to discuss progress on the program in general.

IV. FACTUAL DATA

4.1 Ku-BAND WAVEGUIDE LIMITER MOUNT

In the second quarterly report, experimental results secured on several Ku-band full, half and quarter height limiter mounts were given. During this report, only the full height limiter mounts were investigated. Improvements in the mechanical design of the full height Ku waveguide limiter mount have been achieved through tighter tolerances in the fit of the coaxial shunt stubs and of the center conductor diode mounting studs. The general outline of the Ku-band waveguide limiter mount is shown in Figure (1). Several of these mounts have been fabricated and used in tests to evaluate many varactor diodes. The results have indicated suitable varactors for limiter operation at Ku-band. These diodes are selected for low capacity and high cut-off frequency. Typically $C_j = .22$ pf max., $F_{c-6} = 120$ Gc min., voltage breakdown = 5.5 volts min. PIN limiter diodes have also been evaluated during this period, results have indicated PIN limiter diodes which provide very satisfactory results at Ku-band. However, the insertion loss obtained was on the order of .2 db higher than required for the contract specifications. PIN limiter diodes were evaluated in order to determine their operational characteristics at Ku-band frequencies so that they could be compared against the diode characteristics such as junction capacity, series resistance and voltage breakdown. The results of diode evaluation tests indicated that the limiter diodes selected for Ku-band, both varactors and PIN's, provide satisfactory limiter operation, however, insertion loss was on the order of .2 db higher than desired and isolation

generally was as much as 3 - 5 db less than necessary for high power applications.

4.2 EXPERIMENTAL RESULTS USING PIN AND VARACTOR DIODES

Utilizing the improved full height waveguide limiter mechanical design, PIN and varactor diodes were measured individually. These results can be seen in Figures (2) and (3) respectively. Figure (2) shows performance of a typical PIN diode stage, over the band of interests, 16 to 16.5 Gc. As can be seen, a maximum of .5 db insertion loss and greater than 20 db isolation is obtained. Figure (3) illustrates performance of a typical stage having a value of .8 db insertion loss and greater than 22 db isolation over the 16 to 16.5 Gc band. This data was sufficiently promising to proceed with plans to perform high power testing of both PIN and varactor diodes individually to determine maximum power handling capability of each type. These tests were conducted using high burn out detector diodes for forward bias during high power operation. Figure (4) shows a single switched limiter mount in which the high burn out bias crystal is coupled into the main transmission line through a slot in the side of the waveguide. The amount of coupling of the bias diode is controlled through the parameters of this slot, and the diode is spaced in front of the limiter diode in order to intercept incident power before the limiter diode. High power performance data of a PIN diode is shown for peak powers up to 300 watts in Table I. High power performance data of a switched varactor limiter is shown in Table II for peak powers up to 10 watts peak. Both tables show power input, leakage power output, and bias current supplied to the diodes for each

increment of peak power input. The results shown in Table I and II indicate both PIN and varactor diodes capable of operating at peak power levels sufficiently high enough to warrant further testing of a two stage PIN varactor limiter. Therefore, two limiter mounts spaced 240° electrical degrees between diode centers were tuned and measured using DC bias to simulate high power isolation. The insertion loss, VSWR and isolation for the PIN varactor two stage limiter mount is shown in Figure (5). This mount was fabricated in a single block with the diode spaced 240° between centers. The insertion loss was less than 1 db over a bandwidth from 15.8 to 16.7 Gc, isolation over the same bandwidth was greater than 44 db reaching a maximum of 50 db at 16.3 Gc. The VSWR bandpass characteristic for this PIN varactor limiter mount is also shown in Figure (5). This curve is typical of a two-element filter structure where the spacing is $180 + 60^{\circ}$, both the PIN and the varactor elements are tuned at the low edge of the band at 15.9 Gc. Figure (6) shows the two stage limiter configuration. This configuration also has included a coupling slot for the high burn out detector.

Having completed low level tests on the two stage PIN varactor limiter, further work was carried out to determine the characteristics of the side slot coupled high burn out detector diode. Tests were conducted with many high burn out diodes in order to obtain typical data for detected current versus high power incident. For these tests, a high burn out diode was assembled into a limiter mount omitting the limiter diodes. The output of the high burn out detector was measured across a 10 ohm resistor to ground. Peak power input was applied in increments

from 2 watts up to 4 KW peak power and the current pulse across the 10 ohm resistor was monitored with a dc oscilloscope and a calibrated current probe. Typical data is shown in Table III. A maximum current pulse of 80 milliamperes was obtained for a peak power incident of 1 KW.

4.3 Ku-BAND TWO STAGE LIMITER HIGH POWER RESULTS

The limiter configuration, shown in Figure (6), utilizing the previously described PIN and varactor diodes was measured under high power using a 1 μ sec pulse at a .001 duty cycle. The frequency was 16.25 Gc. Incident power to the limiter was raised in increments from 1 watt peak to a maximum 1 KW peak power, during these measurements, the leakage pulse was displayed on an oscilloscope and the total leakage power was monitored on a power meter. Provisions were also made to monitor bias current provided by the high burn out detector during the tests. The limiter power response is shown in Figure (7). Total leakage power is shown versus peak input power up to 1 KW, it is interesting to note that the total leakage power reached a maximum of 41 μ w as seen in Figure (7).

The leakage pulse is shown in Figure (8) which is a reproduction of the oscilloscope display. The vertical scale in this figure is not linear and was calibrated using a precision variable attenuator and a known reference power level to determine the power levels.

The flat leakage power was 33 milliwatts as shown in using the

following expression:

$$w_s = 10^7 \left(\frac{P_{ave}}{P_{rr}} - P_f T \right) \quad \text{ergs/ pulse}$$

$P_{ave} = 48 \times 10^{-6}$ watts Average Leakage Power

$P_f = 33 \times 10^{-3}$ watts Power Flat

$P_{rr} = 10^3$ CPS Pulse Repetition

$T = 1.0$ microsecond Pulse Width

$$w_s = (.48 - .33) = .15 \text{ ergs/pulse}$$

In this calculation, the flat power energy is subtracted from the total leakage energy. This unit was operated for a period of 6 hours at 1.KW with no deterioration in performance.

Recovery time measurements were made using a fast recovery circuit giving a recovery time of less than 100 nanoseconds when operating with 1 μ s pulse width. The recovery time of the limiter without a fast recovery circuit is largely dependent upon the PIN diode used and will vary from 1.5 μ s to several hundreds of nanoseconds. The fast recovery circuit is used to control the recovery time and reduce the variations due to differences in PIN limiter diodes. The technique of measuring recovery time and fast recovery circuits can be found in detail in the 4th Quarterly Technical Report, PEM Contract DA 36-039-SC-86718, Solid-State Microwave TR-ATR Switch.

V. CONCLUSIONS

Experimental work to date has resulted in the successful performance of an experimental two stage PIN varactor switched limiter. This device has been measured at peak powers up to 1 KW with leakage power very closely approaching the major goals of the Ku-band portion of this contract. Further testing under high power will be required in order to determine the maximum power limitations of this limiter. In addition, further efforts will be required to reduce insertion loss and size.

VI. PROGRAM FOR THE NEXT INTERVAL

Plans for the next interval are to continue high power testing of the two stage PIN varactor limiter and to continue the investigation of diodes and new diode package configurations in order to obtain lower insertion loss and higher isolation per diode. Additional efforts will be directed to reducing the limiter module size using smaller diode mounting studs and choke assemblies so as to achieve a design of a two stage limiter considerably smaller than the model described in this report.

VII. IDENTIFICATION OF KEY TECHNICAL PERSONNEL

<u>Name</u>	<u>Title</u>	<u>Man Hours</u>
R. Tenenholtz	Group Leader	3.0
R. Brunton	Project Engineer	167.0

TABLE I

PIN SWITCHED LIMITER
HIGH POWER OPERATION

<u>PEAK POWER</u> <u>INPUT</u>	<u>LEAKAGE POWER</u> <u>OUTPUT (AVG.)</u>	<u>PEAK BIAS</u> <u>CURRENT</u>
Watts (Peak)	Watts (Avg.)	ma
0.125 watts peak	0.125 mw avg.	---*
0.25	0.228	---
0.5	0.36	---
1.0	0.36	---
2.0	0.26	4 ma
4.0	0.25	8
8.0	0.29	16
16.0	0.385	28
32.0	0.51	50
64.0	0.735	78
128.0	1.26	88

* Peak Bias Current below 2 ma was not measurable with the equipment used in these tests.

TABLE II

VARACTOR SWITCHED LIMITER
HIGH POWER OPERATION

<u>PEAK POWER</u> <u>INPUT</u>	<u>LEAKAGE POWER</u> <u>OUTPUT (AVG.)</u>	<u>PEAK BIAS</u> <u>CURRENT</u>
Watts (Peak)	Watts (Avg.)	ma
0.02 watts peak	0.014 mw avg.	---*
0.2	0.034	---
1.0	0.039	---
2.0	0.043	2 ma
4.0	0.053	6
8.0	0.070	13
16.0	0.115	24
32.0	0.256	42

* Peak Current below 2 ma could not be measured.

TABLE III

HIGH BURNOUT DETECTOR DIODE
HIGH POWER OPERATION

<u>PEAK POWER</u> <u>INPUT</u>	<u>PEAK CURRENT</u> <u>10 OHM LOAD</u>
1,000 watts	80 ma
500	54
250	34
160	28
80	19
40	11
16	7
8	3
4	2
2	1

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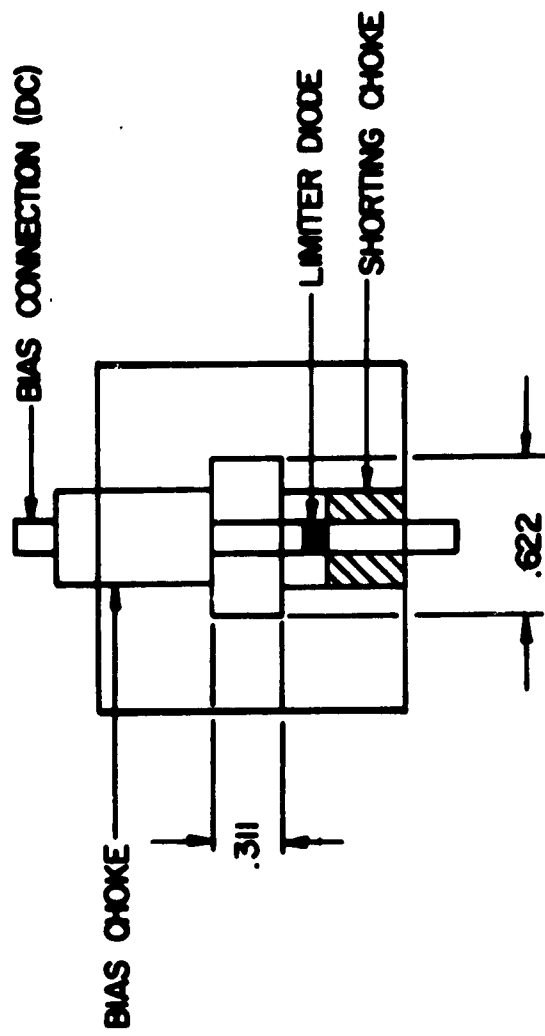


FIGURE 1

OUTLINE KU BAND WAVEGUIDE DIODE LIMITER MOUNT

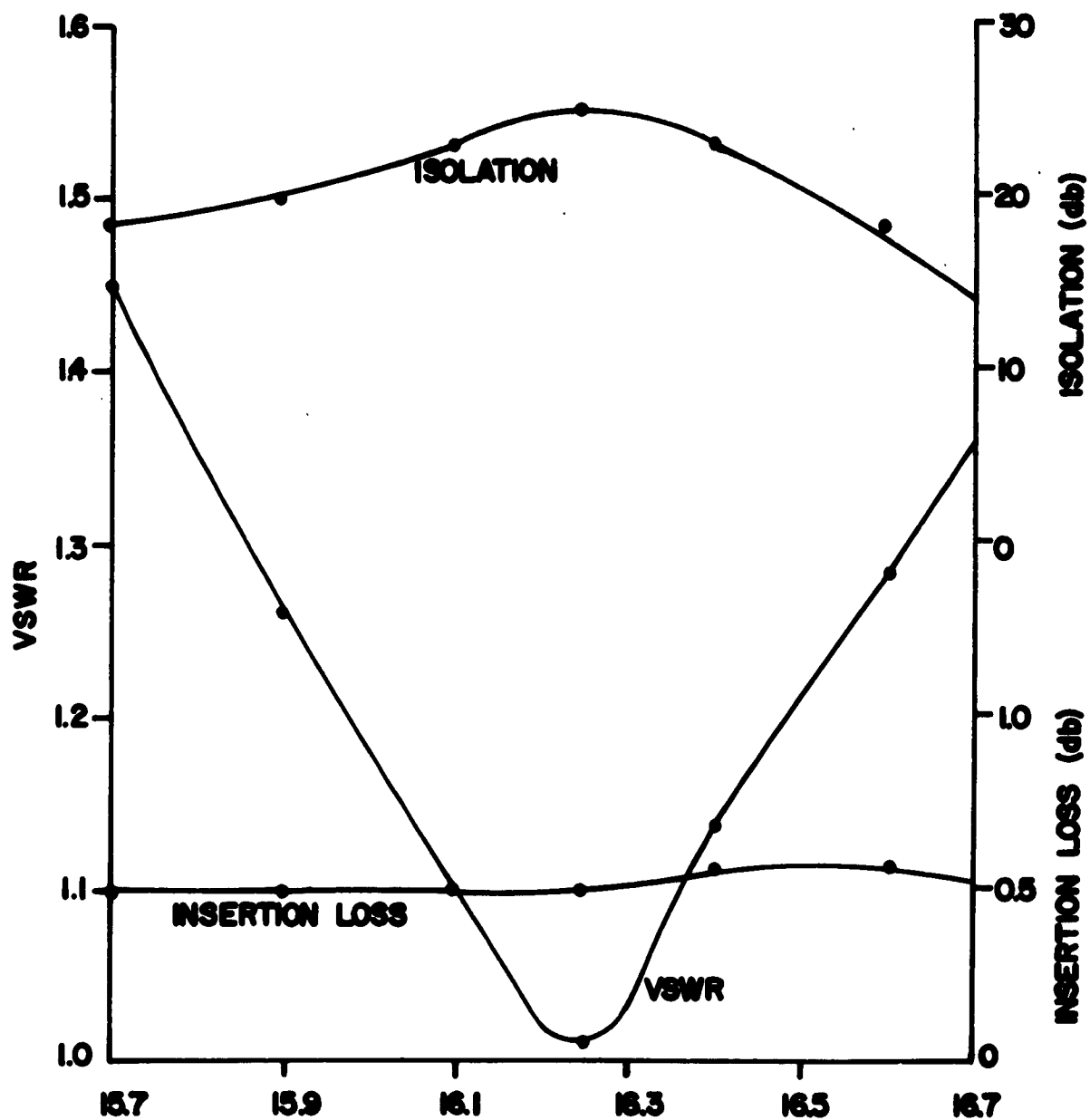


FIGURE 2

LOW LEVEL CHARACTERISTICS FOR A
PIN DIODE IN A KU BAND WAVEGUIDE
LIMITER MOUNT

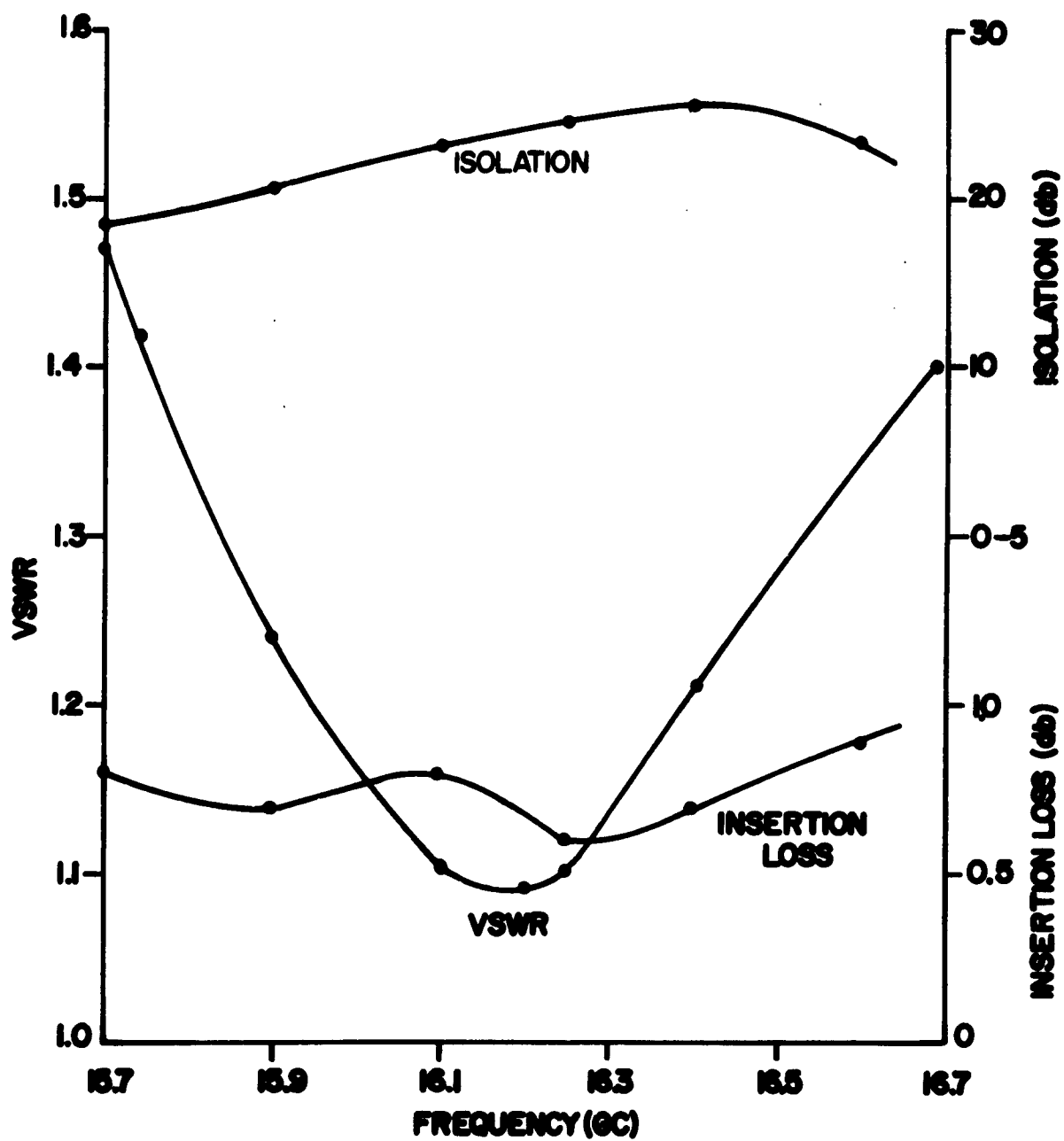


FIGURE 3

LOW LEVEL CHARACTERISTICS FOR A
VARACTOR DIODE IN A Ku BAND WAVEGUIDE
LIMITER MOUNT

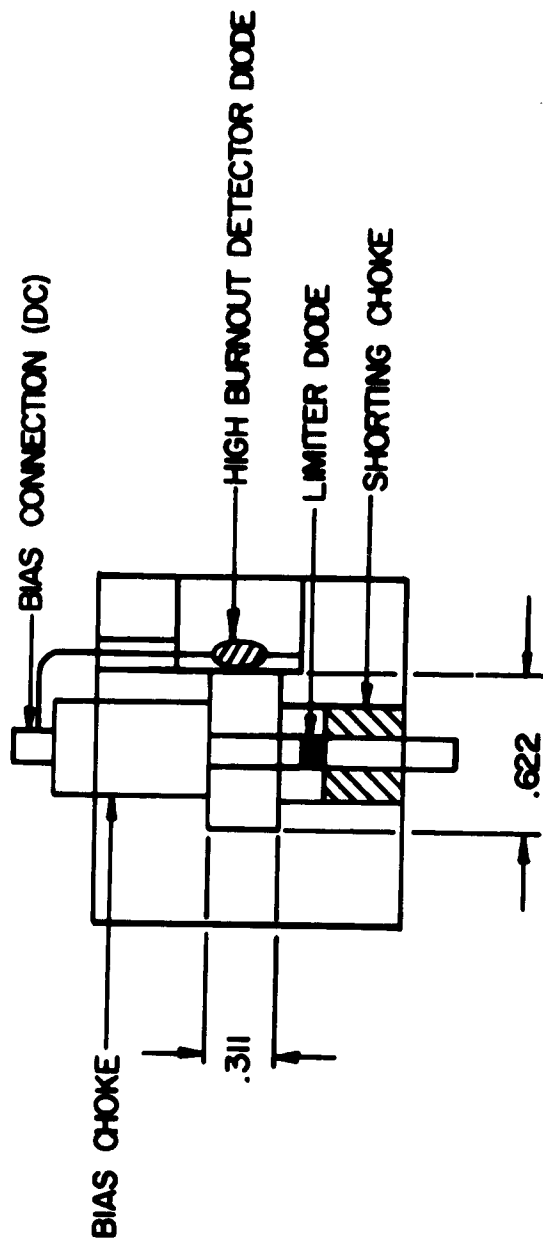


FIGURE 4

OUTLINE KU BAND WAVEGUIDE SWITCHED LIMITER MOUNT

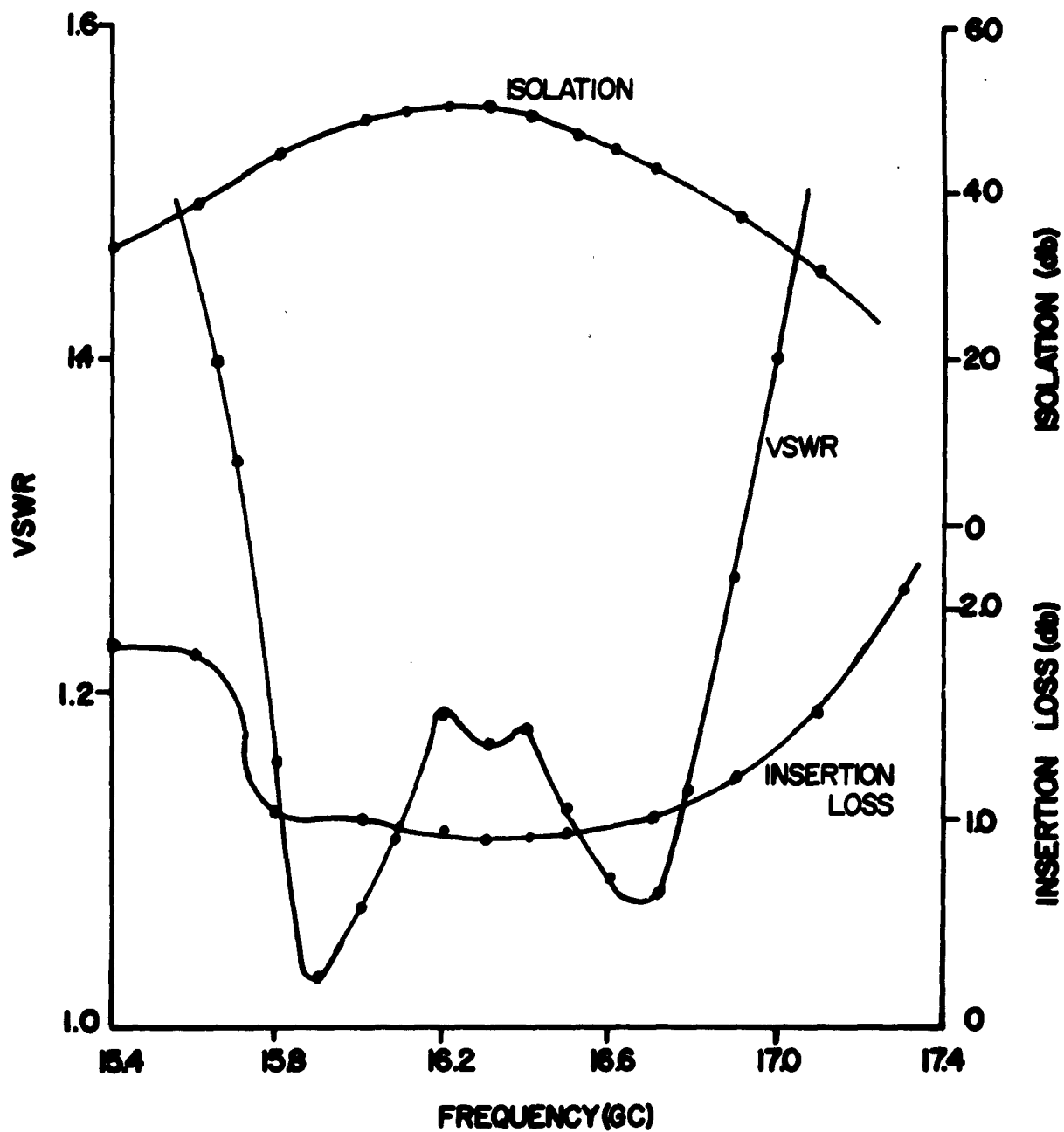


FIGURE 5

LOW LEVEL CHARACTERISTICS FOR A
PIN, VARACTOR TWO STAGE LIMITER MOUNT

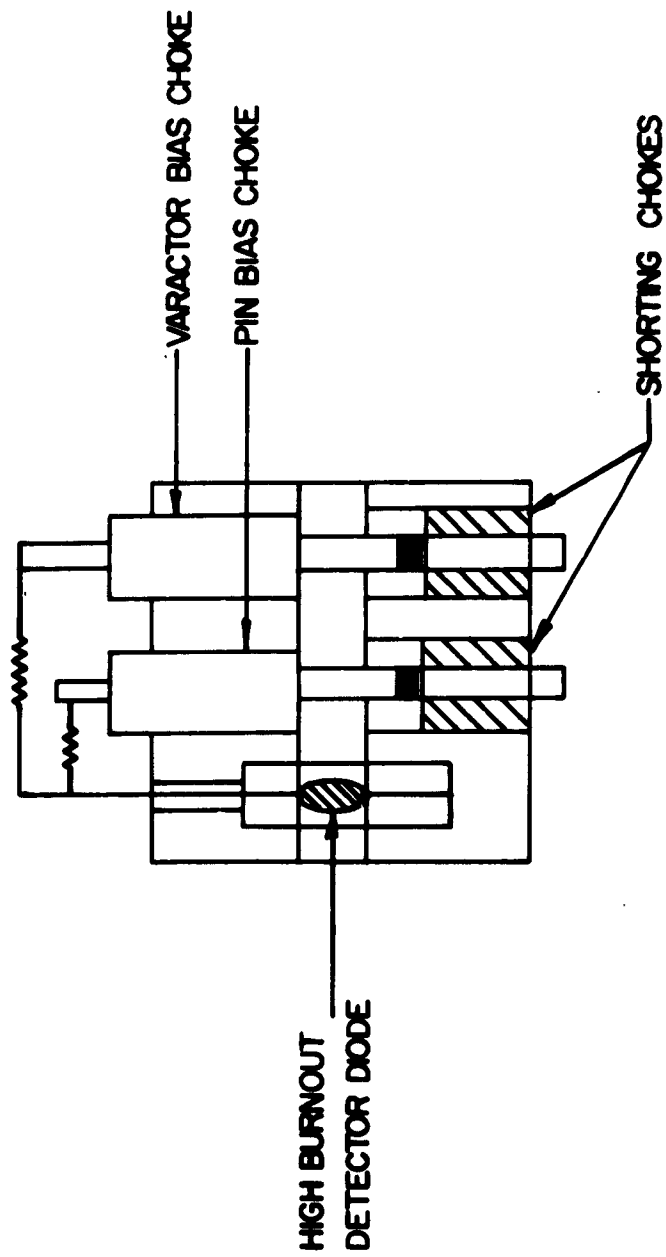


FIGURE 6

TWO STAGE PIN, VARACTOR SWITCHED LIMITER MOUNT

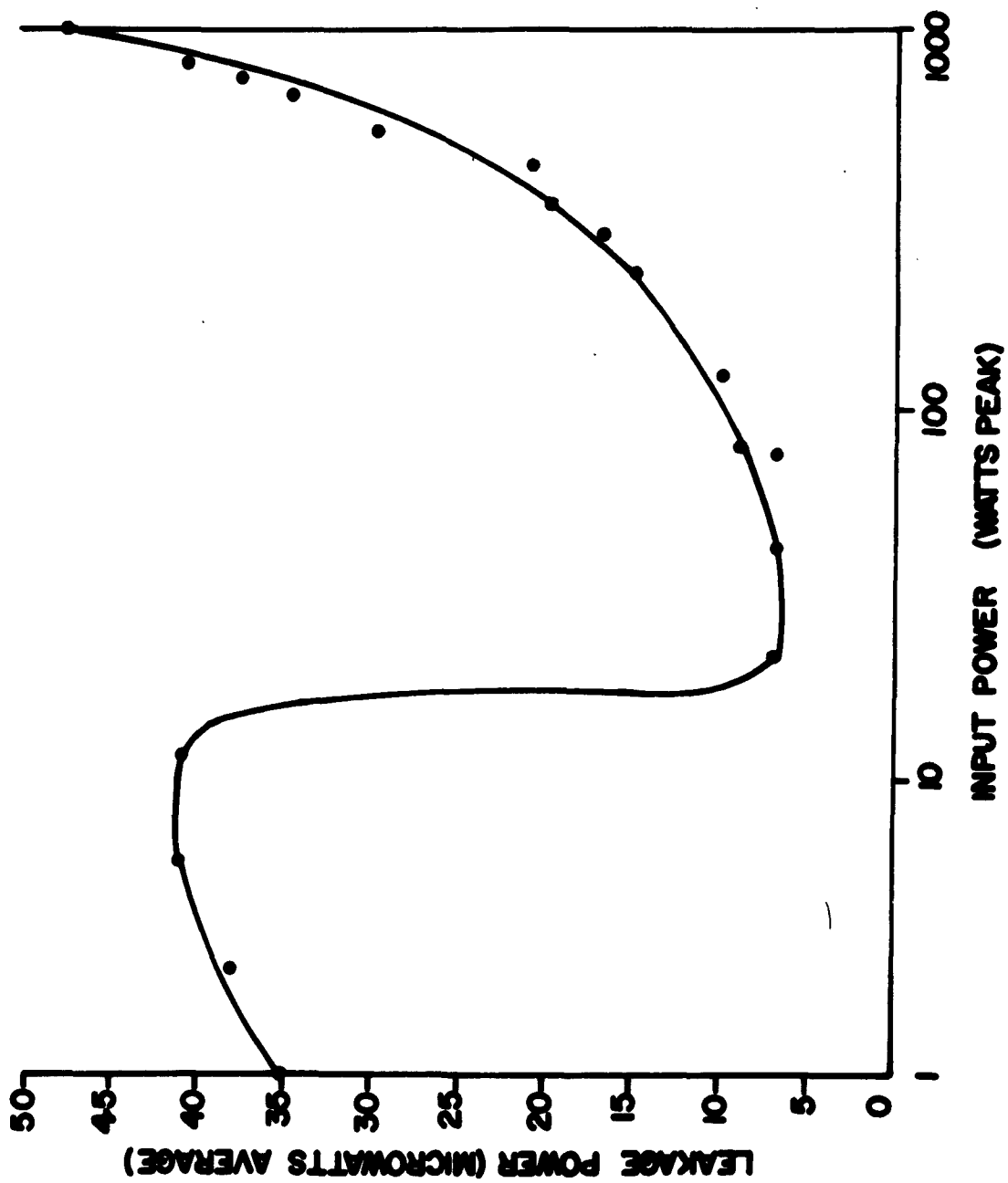


FIGURE 7

TWO STAGE PIN, VARACTOR SWITCHED LIMITER TOTAL LEAKAGE

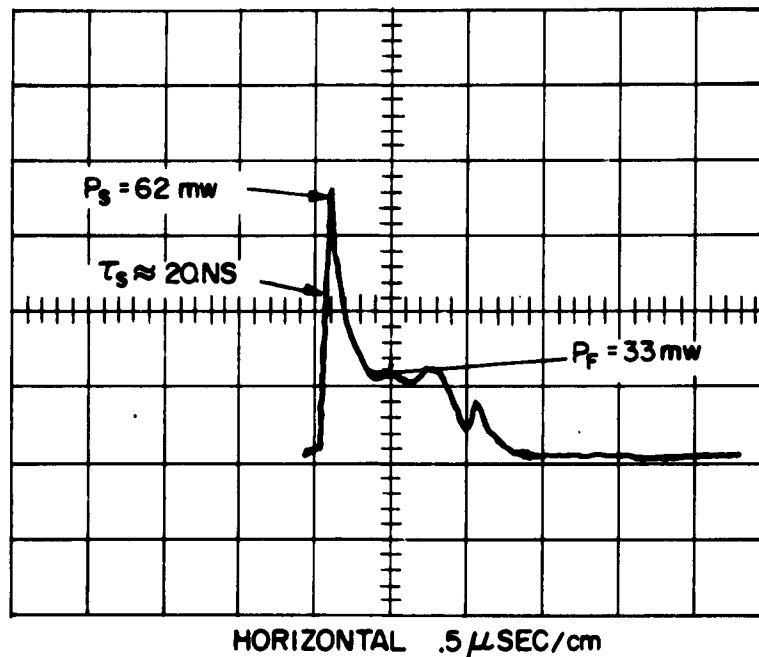


FIGURE 8
TWO STAGE PIN, VARACTOR SWITCHED LIMITER, HIGH
POWER LEAKAGE PULSE FOR 1 KW OPERATION

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3rd Quarterly Report
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